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PECAN ROSETTE IN RELATION TO SOIL DEFICIENCIES.

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SERIOUSNESS OF THE DISEASE.

The so-called rosette is considered generally by growers to be the most serious trouble to which pecan trees are subject, and this opinion is justified by the facts. Probably 10 to 20 per cent of the pecans planted in orchards in the southeastern United States have shown this trouble in a more or less marked degree, and the resulting loss of tree growth and nut production undoubtedly has been great.

In its earliest stages the disease is indicated by a few small, wrinkled, yellow-mottled leaves at the ends of the branches. All gradations of the disease are found between that shown by these first symptoms and the condition illustrated in figure 1, where the tree is dying back. The writer has never seen a tree which has died entirely as a direct result of rosette, but affected trees become so weakened that frequently they are killed by winter injury and borer attacks. Seriously affected trees rarely bear nuts, and they make but little growth.

PREVIOUS WORK.

Investigations conducted by the United States Department of Agriculture[1] between 1902 and 1913 showed that no parasitic organ-

[1] Orton, W. A., and Rand, F. V. Pecan rosette. *In* Jour. Agr. Research, vol. 3, no. 2, p. 149–174, 1916.

ism was associated with the diseased trees and indicated rather definitely that the cause of the trouble lay in the soil; but whether this cause was physical, chemical, biological, or a combination of the three was not indicated.

PRESENT INVESTIGATIONS.

In 1914 investigations of the disease were taken up by the writer, and an effort was made to find some common factor running through a large number of cases. Without such a common factor an infinite variety of empirical experiments was the only recourse. With this preliminary problem in mind, the examination of a large number of affected orchards was undertaken. Orchards between central Florida and eastern Louisiana were visited, and while the disease was seen to be present on a wide range of soil types and under various conditions of cultivation and fertilization, one factor seemed to stand out prominently.

FIG. 1.—A typical badly rosetted tree in one of the stable-manure plats in September, 1915. The same tree is shown in figures 2 and 3.

THE COMMON FACTOR IN PECAN ROSETTE.

A marked difference in the amount of the disease in different localities was found. On the river flood-plain soils of southern Louisiana the disease is practically unknown. Only two individual cases have ever been reported to State or Federal pathologists from that State. The soil is deep and black, of high fertility, and presumably of high water-holding capacity as compared with the typical sand, sand-

clay, and clay soils of the Atlantic and Gulf coastal plains, where the disease is so widely prevalent.

Quite as striking a difference in the distribution of the disease was found within the States of Georgia and Florida. A very large proportion of the diseased trees, probably 90 per cent or more, was found on the hilltops and slopes. Occasional cases or groups of cases were on bottom lands, but all of these that have been examined have been found to be growing in deep sand or else in a clay or sand clay underlain at 2 to 3 feet by sand. It was observed also that wherever the conditions were such as to produce any quantity of rosette, the weeds or crops growing in the tree rows had a stunted, yellow, unthrifty appearance as compared with those growing among healthy trees and that large, healthy trees, 5 to 10 years old, frequently showed marked signs of the disease the first year after being transplanted. On the other hand, trees planted in low places in which humus and fertility had accumulated from year to year were uniformly vigorous, thrifty, and free from the disease.

FIG. 2.—The tree shown in figure 1 after receiving the stable-manure treatment for one and one-half seasons. July, 1917.

While apparently contradictory cases occasionally are seen, 90 per cent or more are surrounded by conditions that plainly indicate a deficiency of humus, plant-food material, and moisture. Either where the soil or topography is such that there is a deficiency of this combination, or where the tree's condition is such as to interfere with its obtaining an adequate supply of plant-food material, the result appears to be the same, i. e., a yellowing of the foliage, a shortening of the internodes, a pushing out of dormant buds, and in many cases a dying back of the twigs and branches.

The facts pointed very strongly to the rosetting of pecans being an evidence of bad soil conditions—a deficiency in humus, fertility, and

moisture supply; and field experiments to determine this matter definitely were begun in the fall of 1915.

THE EXPERIMENTS.

If it were true that pecan rosette is merely an evidence of starvation, it might be supposed that liberal applications of mineral fertilizers would relieve the condition, but such is not the case. Experiments by the United States Department of Agriculture with heavy applications of mineral fertilizers in young orchards located on poor soil, as well as the experience of many growers, indicate clearly that rosetted trees generally become worse under such treatment. This point, taken in connection with the facts that the native habitat of the pecan in the United States is the flood plains of the Mississippi River, its tributaries, and other streams of the South and Southwest and that pecans make a uniformly vigorous, healthy growth on these soils, indicated that the fertility to be added should be from organic sources and that the physical condition and water-holding capacity of the soil must be improved in order to overcome the disease. Only by the annual addition to the soil of large quantities of humus-forming material could this result be obtained.

FIG. 3.—The tree shown in figures 1 and 2 after two complete seasons. There has been some normal loss of foliage, but striking improvement is evident. October, 1917.

PURPOSE OF THE EXPERIMENTS.

The experiments were designed to demonstrate the correctness or incorrectness of the view stated above. It was proposed to increase the humus content and the fertility of the soil and thereby to better its physical condition and water-holding capacity as rapidly as pos-

sible by means of heavy applications of stable manure and cottonseed meal and by the use of legumes.

In the experiments the most economical method of obtaining these results was left out of consideration for the time being. If the correctness of the principle could be established, the cheapest method of arriving at the desired results in actual orchard practice could be worked out by later experiments. Therefore, in order to secure quick results, much heavier applications of fertilizers were made than would be used in commercial practice.

Three experiments, including about 13 acres of pecans in three orchards in southern Georgia, were begun in the fall of 1915. The three tracts were divided into plats, with suitable checks. Three plats, one in each tract, received stable manure alone at the rate of 20 tons to the acre; two received stable manure at the same rate, and in addition cottonseed meal at the rate of 1 ton to the acre; and two received cottonseed meal alone at the rate of 1 ton to the acre. The stable manure was applied in the fall, and the three tracts were then plowed; the cottonseed meal, analyzing 6¾ per cent ammonia, was applied in the following April. In the fall of 1914 lime alone was applied to a separate plat in one of the tracts at the rate of 3 tons to the acre of ground limestone (unburned). From April until June clean culture was maintained with harrows in all the plats, and they were then sowed to cowpeas. These were permitted to grow until killed by frost, when they were plowed under, and then the entire program was repeated except that the cottonseed meal was omitted in the second year. The check plats received the same cultural treatment, but no fertilizer. This program has been followed without material variation for two years. The trees in two of the tracts were 6 years old and in the third 10. None had ever borne a crop. The most that had ever been obtained from the 10-year-old trees was a few scattered nuts. The soils in the three tracts were not well suited to conserve, or, when needed, give up moisture. This was largely due to the heavy clay subsoils with insufficient surface soil.

RESULTS OF THE EXPERIMENTS.

The results of the work for the past two seasons on the three experimental tracts have been compiled in Table I. The fact that the amount of rosette normally fluctuates to some extent makes this the fairest way of presenting the results. Practically no results were obtained during the first season.

In Table I the term "badly rosetted" indicates trees which are dying back and "rosetted" those which are yellow and making but little growth. Trees showing merely a trace of the disease were

considered healthy, as bearing trees not infrequently show traces of the disease at the end of the growing season.

At the beginning of the experiments there were in the fertilized plats 56 badly rosetted trees, 11 rosetted, and 21 healthy. After two years the number of badly rosetted trees in the fertilized plats was reduced to 7, and 26 were in the rosetted class—i. e., partially recovered. The number of healthy trees had been increased from 21 to 53. Two trees had been killed by winter injury.

During the same period the healthy trees in the check plats had decreased from 29 to 17, the rosetted had increased from 13 to 24, and the badly rosetted had decreased from 38 to 37. Two were dead from winter injury.

TABLE I.—*Effect of the use of selected fertilizers for the control of pecan rosette in southern Georgia during the seasons of 1915 and 1917.*

Fertilizer used.	Number of trees.	Date of observation.	Badly rosetted.	Rosetted.	Healthy.	Dead.	Percentage of healthy trees.
Stable manure	46	September, 1915	29	10	7	.....	15
		October, 1917	2	19	24	1	53
Stable manure and cottonseed meal	15	September, 1915	8	1	6	.....	40
		October, 1917	1	2	12	.....	80
Cottonseed meal	27	September, 1915	19	.....	8	.....	29
		October, 1917	4	5	17	1	65
Lime	46	September, 1915	27	16	3	.....	6.5
		October, 1917	45	1	.....	.....	0
Check (not fertilized)	80	September, 1915	38	13	29	.....	36
		October, 1917	37	24	17	2	21

DISCUSSION OF THE EXPERIMENTS.

The figures presented in Table I convey but an inadequate idea of the striking change that has taken place in the fertilized plats. Figure 1 shows a typical badly rosetted tree at the beginning of the experiments in September, 1915. Figures 2 and 3 show the same tree in July and October, 1917, respectively. This tree received stable manure alone, but the striking improvement shown is quite typical of that noted in all the fertilized plats. Larger leaves of dark-green color and a marked increase in the circumference of the trunks of the trees in the fertilized plats made the contrast with the unfertilized plats most striking.

Only one lot of trees in these experiments was old enough to bear nuts. Of this lot 14 received the stable-manure treatment and 33 were used as checks and received no fertilizer. These trees were 12 years old in 1917. The 14 fertilized trees produced 197 pounds of nuts the second season, and the 33 unfertilized checks produced 10 pounds.

In the last analysis the production of nuts will give the real measure of the success of these experiments and the proof of the

correctness of the view that pecan rosette is due to a deficiency of humus, plant-food material, and soil moisture. Consequently, it will probably be three or four years more before definite and conclusive results can be had, but the improvement obtained during the first two years, together with the other evidence presented, makes a striking case, and it appears reasonably certain that the improvement in the fertilized plats will continue until rosette is practically eliminated and nut production established in all of the fertilized trees.

LIME AND ROSETTE.

The use of lime as a remedy for pecan rosette has been strongly urged by some growers, and there appears to be a rather widespread belief in its efficacy for this purpose. Apparently this belief is based on the assumption that the disease is due to acid soil. That there is little or no reason for making such an assumption will be evident from a consideration of the facts in the case.

The soils of the native habitat of the pecan—i. e., river flood plains—are practically all acid and yet rosette is a rarity on such soils. Practically all of the soils of the Atlantic and Gulf Coastal Plains are acid, yet as a whole the orchards planted on these soils show probably not more than 20 per cent of the trees rosetted.

Tests for acidity by the litmus method have been made of soil from around 53 trees. The samples were taken to a depth of 4 feet and each foot tested separately. Of the 30 samples from rosetted trees, 29 gave acid reactions and 1 was neutral. Of the 23 samples from healthy trees, 18 gave acid reactions and 5 were neutral.

In the lime test, the results of which are given in Table I, the trees in the plat which received lime alone at the rate of 3 tons of ground limestone to the acre not only failed to improve, but were worse at the end of the third season following its application.[1]

There appears to be no reason to suppose that lime will be of any direct benefit in the treatment of pecan rosette. That it may be of indirect benefit in improving the physical condition of certain soils and in promoting the growth of legumes is highly probable, and when lime is used in rosetted pecan orchards this relation should be kept in mind.

THE ROOT SYSTEM AND ROSETTE.

The fact that the pecan develops a long taproot probably explains the view so commonly held by growers that the tree draws largely on the subsoil for its plant-food material. The facts of the case are

[1] Similar results were obtained by Rand in experiments with lime. For details of these experiments, see Orton, W. A., and Rand, F. V., Pecan rosette, in Jour. Agr. Research, vol. 3, no. 2, p. 149–174, 1916.

that the feeding roots of the pecan are distributed through the surface soil, and in proportion as this is deep and fertile the tree does well, but where the surface soil is of insufficient depth and lacking in humus and fertility the tree is likely to become rosetted. Prolonged hot, dry weather not infrequently kills many of the feeding roots in shallow surface soils. In plowing such land large numbers of roots

FIG. 4.—A 10-year-old pecan tree, showing taproot and main laterals intact. Practically all the laterals originated within 18 inches of the surface of the soil. Nearly all the small feeding rootlets originating on the laterals were found in the upper 6 to 8 inches of soil.

up to an inch or more in diameter are cut by the plow, and it appears that this must aggravate the disease in some degree.

It remains for experimentation to determine just how serious a matter is this drying out and cutting of the roots of rosetted trees. Meantime it would appear to be the part of good practice to develop a deeper surface soil between the rows of trees by the use of cover crops and by deepening the plow furrows from year to year until 8 to 10 inches of fertile surface soil is established and to avoid as

much as possible the cutting of the roots by plowing shallow close to the trees.

Figure 4 shows a 10-year-old pecan tree which was carefully dug so that as much of the root system as possible might be obtained. This tree was growing on a stiff clay hilltop where the soil was only moderately fertile. The white band indicates the ground line. The taproot and all of the main lateral roots are shown intact. The chief point of interest is that practically all of the laterals originated within 18 inches of the ground line, and even at 12 to 15 feet from the tree they were rarely found deeper than 20 to 24 inches below the surface. The small fibrous roots originating on the main laterals may be seen plainly. Practically all of these small roots were found in the surface soil.

PREVENTION AND CONTROL.

The experimental and other evidence indicates very strongly that pecan rosette is a sign of a soil deficient in humus, fertility, and moisture supply, and certain conclusions with reference to the control of the disease in established orchards as well as its prevention in those yet to be planted may be drawn therefrom.

In setting new orchards it would be the part of sound judgment and economy to plant only on good land or land which is susceptible of rapid and permanent improvement. Deep sand, clays underlain by sand, and eroded hillsides should be avoided.

After the orchard is planted the cultural practices should be such as to increase the depth, humus content, fertility, and moisture-holding capacity of the surface soil as rapidly as possible and to conserve moisture during dry periods. Prolonged periods of dry weather during the spring are the rule rather than the exception in the southeastern United States. Consequently, the interplanting of a diseased orchard to shallow-rooted crops which require frequent cultivation, as, for example, cotton or peanuts, appears to be a desirable and economical way of obtaining this result. The constant addition of large quantities of humus-forming materials, thereby both bettering the physical condition of the soil and increasing its water-holding capacity and fertility, is absolutely necessary to produce healthy trees from those already diseased and to prevent the development of new cases of rosette.

THE USE OF COVER CROPS.

These results can be obtained in a variety of ways. Legumes, such as cowpeas, velvet beans, or soy beans, may be sown in the orchard in June and turned under in the late fall or winter. Fall and winter cover crops, either leguminous or nonleguminous, may also be used

and plowed under green in the spring before the trees have started their growth. Just what procedure should be followed depends on the conditions connected with each orchard. But whatever the conditions may be, some definite and consistent soil-building policy should be adopted in the pecan orchards of the South if rosette is to be overcome and healthy productive orchards maintained. The program of work should involve the growing of one crop, preferably a legume, which may be returned to the soil. This procedure should be accompanied by the gradual deepening of the plow furrows until 8 or 10 inches of surface soil is turned over annually.

In this connection it is only necessary to add that intercrops which draw heavily on the soil moisture in the spring, such as oats, have a very undesirable effect on the trees by checking their growth, and they undoubtedly aggravate the disease. Consequently, such crops should never be allowed to mature in the orchard, but when used should be turned under about the time tree growth is starting.

THE USE OF FERTILIZERS.

Definite advice can not be given on the use of commercial fertilizers until adequate experimental data are available. Meantime, it would appear from the experiments which have been conducted and from the writer's general knowledge of the situation that the best course to follow is to use them on such intercrops as may be planted rather than to attempt to produce healthy trees by the direct use of such materials.

In these experiments, heavy applications of stable manure, cottonseed meal and stable manure, and cottonseed meal alone, in connection with legumes, have proved highly beneficial to rosetted trees. Inasmuch as the supply of stable manure is so limited, the orchardist must of necessity place his main dependence for soil improvement upon the consistent use of legumes or other crops which may be returned to the soil, together with the judicious use of commercial fertilizers to promote the growth of these crops. Legumes have the advantage of adding nitrogen to the soil as well as increasing its humus content and water-holding capacity and are for that reason to be preferred to other intercrops for improving the soil. Whether the tops of such soil-building crops are to be turned under, grazed off, or cut for hay is largely a matter of economics, and the individual grower must determine which is the best course for him to follow. While the soil will be improved and the disease overcome more rapidly by turning under the entire crop, it may be and probably would be the more profitable course in the South at the present time to utilize the tops for hay.

IMPORTANCE OF PROPER SOIL.

The newness of the pecan industry, the rapidity with which it has spread over a wide territory, and the general lack of knowledge of the tree's requirements have led to the planting of many orchards and portions of orchards in situations which are totally unsuited to the production of healthy trees. A large proportion of the cases of rosette in the Southeast are due to such plantings. While it is entirely possible to reclaim practically all of them and develop healthy trees from the diseased ones, it will probably not be profitable to do so in many cases. On deep sand, clay underlain with sand, and on badly washed hillsides the difficulty and expense of sufficiently increasing and maintaining the soil fertility will be such that it is hard to see any justification in attempting it, particularly in view of the fact that vast areas of suitable pecan lands at reasonable prices are available.

On the other hand, where the disease is present on soils which are readily susceptible of permanent improvement, it would probably be cheaper and more profitable to build up such soils and thus develop healthy bearing trees rather than to replant in a new location.

The matter is thus seen to be one of soil deficiency, and the answer to the pecan-rosette problem is very evidently "soil improvement." In proportion as the soils in the orchards are made to approach the condition of those found in the native habitat of the pecan in humus and plant-food content and in water-holding capacity, the disease may be expected to decrease and eventually to become reduced to a negligible factor, if not entirely eliminated.

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